FlatLand → MicroLand → NanoLand

Metrology and Standards: Challenges in Micro/Nano Materials and Systems

NIST USMS Workshop
September 22, 2005

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FlatLand → MicroLand → NanoLand

Outline

- Micro Standards Topics
  - SEMI MEMS
    - Wafer Bond Targets
    - Bond Integrity Tests
    - Bond Strength Tests
    - Terminology
    - Fluidics Design Guide
  - ASTM Film Stress Tests

- Nano Standards Topics
  - -- SEMI Nanoparticles
  - -- IEEE Carbon Nanotubes (CNT)

- Other NANO Activities
  - ISO TC229 on Nanotechnologies
  - ANSI NSP (Nanotechnology Standards Panel)
  - ASTM Committee E56 on Nanotechnology

FlatLand → MicroLand → NanoLand

- FlatLand
  - Edwin A. Abbott's classic tale of interdimensional experience: **http://www.alcyone.com/max/lit/flatland/**
  - What we think we see based on CMOS
- MicroLand
  - What we think we know
- NanoLand
  - What we think we imagine

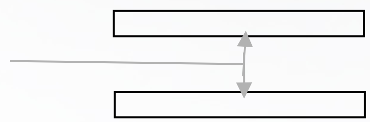
MicroLand

SEMI MEMS Wafer-Wafer Bonding Activity

- *Doc 3950 – Guide to Specifying Wafer-Wafer Bond Alignment Targets*
  - March 05: Initial Ballot
  - August 05: International Ballot
- Wafer Bond Tests
  - Integrity (Voids)
    - Surveyed Test Equipment Users, Suppliers
    - Interpretation underway
    - Guide for Specifying Equipment – Draft 1/October
  - Strength
    - Micro-Chevron test
    - Work starting Oct 2005

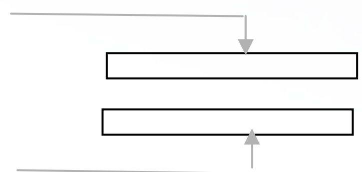
Wafer Alignment Processes

- ISA – Inner Substrate Alignment



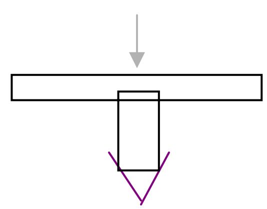
Balloted July05

- BSA – Back Substrate Alignment



Balloted July05

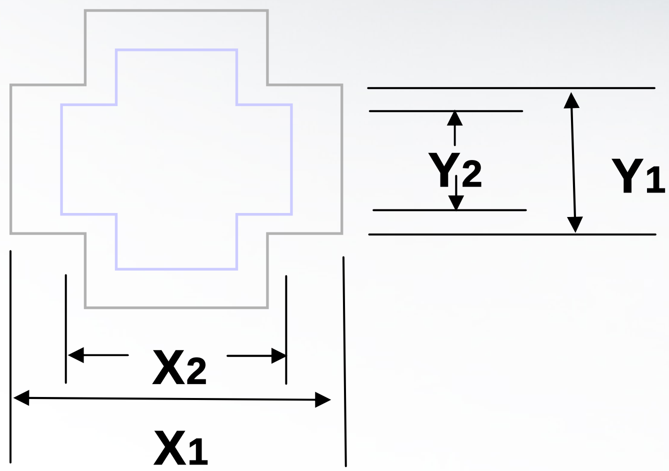
- TSA – Top Substrate Alignment



Not balloted
Future Consideration

Suggested Alignment Targets

Geometry



Example

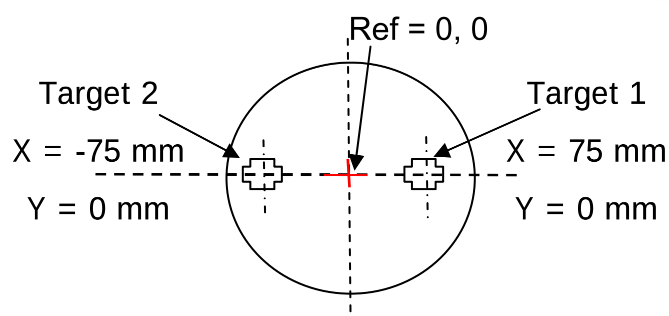
X1 = 50 µm ± 5 µm

X2 = 40 µm ± 4 µm

Y1 = 50 µm ± 5 µm

Y2 = 40 µm ± 4 µm

Location

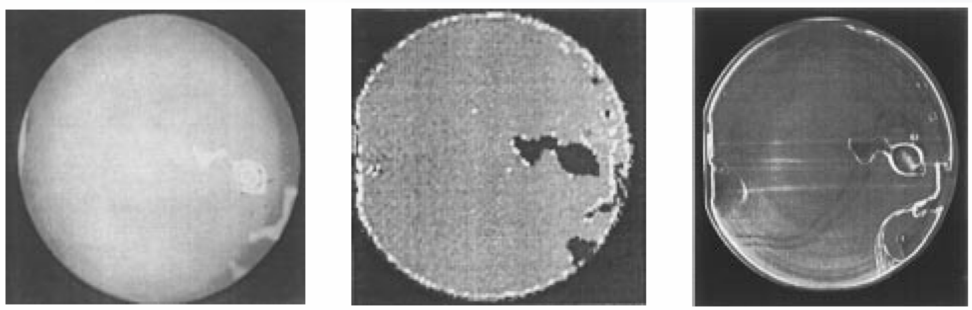


MEMS Materials Characterization TF
Wafer Bond Tests

- Bond Integrity Survey
  - Distributed in April to Metrology Tool Makers
- Returns – Metrology Tool Suppliers/Users
  - 5 IR Transmission, 4 Ultrasound, 1 X-Ray Topography
  - Summary Comparison / Analysis
    - In Progress
  - Draft “Guide for Selecting Wafer Bond Integrity Measurement Systems”
    - Draft 1 – October, Portland OR discussion

Bond Integrity Inspection Issues

- **Nondestructive evaluation of bond interface is critical for quality control in wafer-wafer bonding processes**
- **Several methods have been used:**



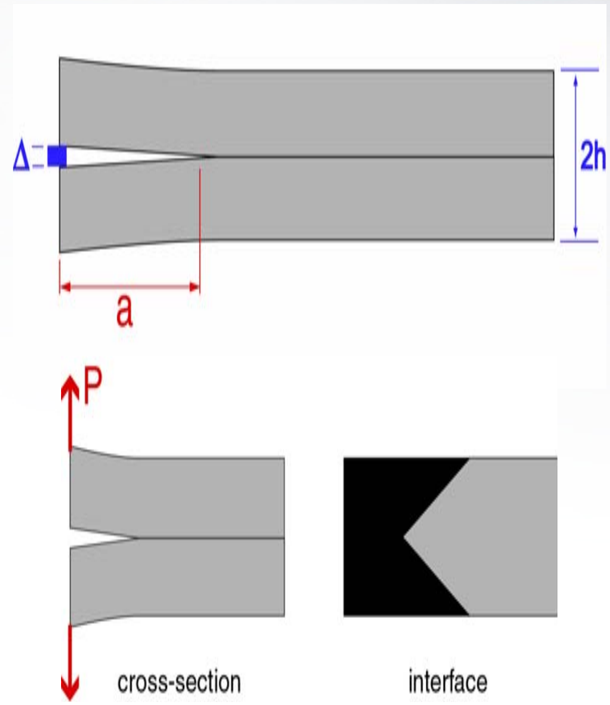
IR transmission ultrasound x-ray topography

Images from M. Schmidt, Proc. IEEE 86:1575 (1998)

- **Differing gap and spatial resolutions, process compatibility, suitability for certain materials systems, etc.**
- **Qualitative understanding of differences between methods exists, but quantitative limits are unclear**
- **<u>GOAL: Develop table of inspection methods and attributes that facilitates user selection of techniques</u>**

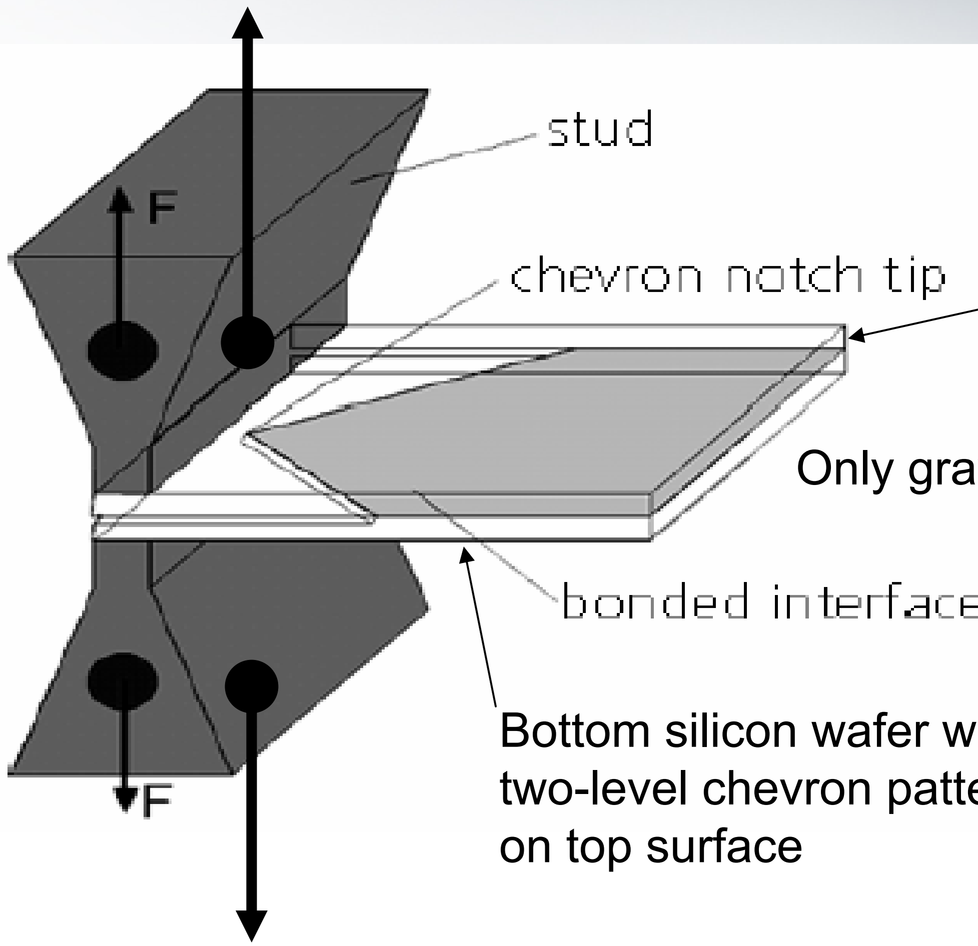
MEMS Materials Characterization TF
Bond Strength Test

- Interface Strength Affected By
  - Wafer Pre-treatment
  - Bonding Conditions
- Test Types
  - Crack Propagation
    - Large physical sample size, Measurement Uncertainty
  - Chevron
    - Smaller physical sample size, Improved Measurements
  - Micro-Chevron
    - Smallest samples, High spatial resolution/precision
    - Spatial Strength Distributions



Provides a measure of the interface toughness – units of energy/area – J/m²

Micro-Chevron Testing

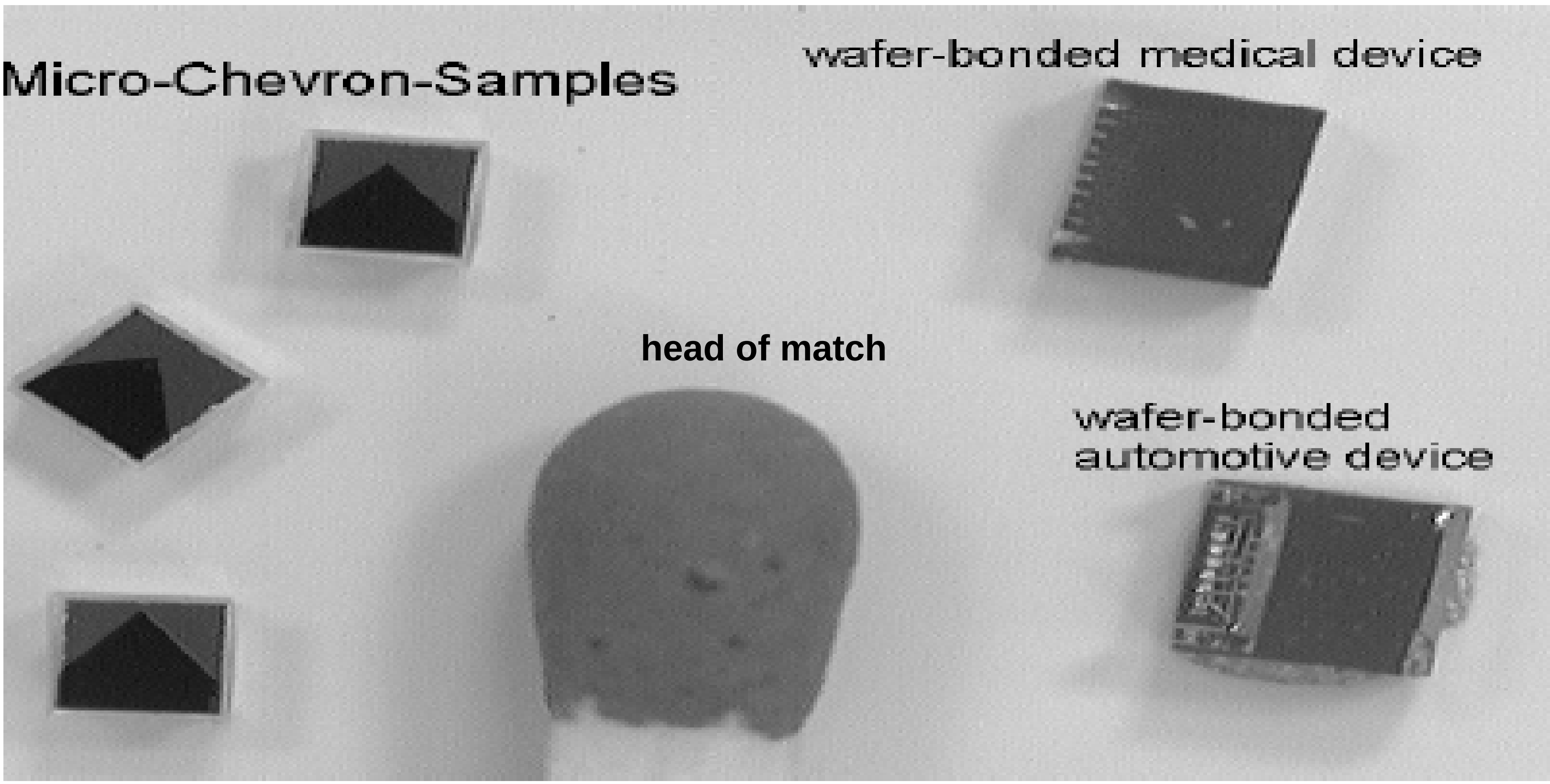


Top silicon wafer with un-patterned bottom surface

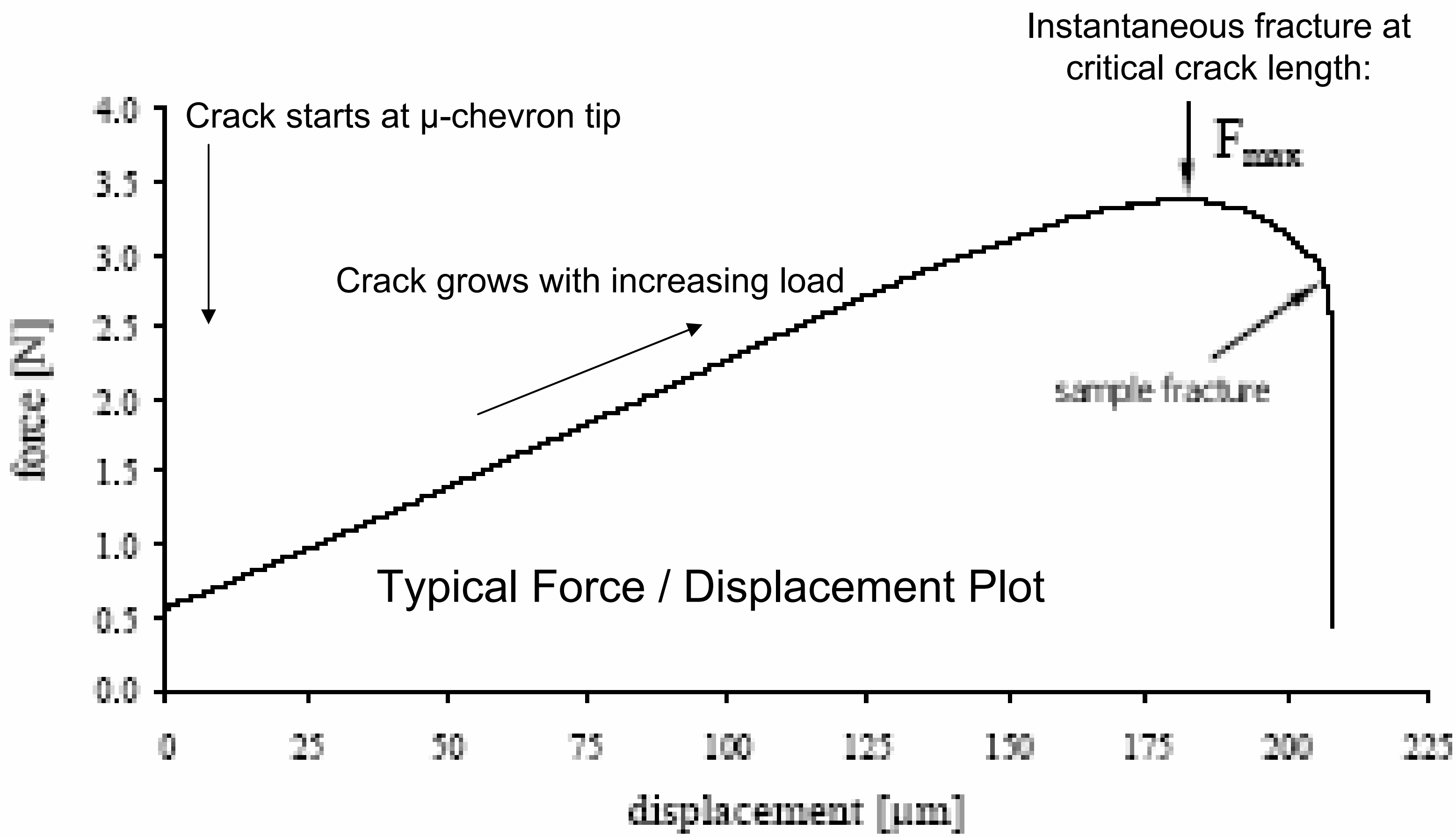
Only gray area is bonded

Bottom silicon wafer with two-level chevron pattern on top surface

Micro-Chevron Comparison

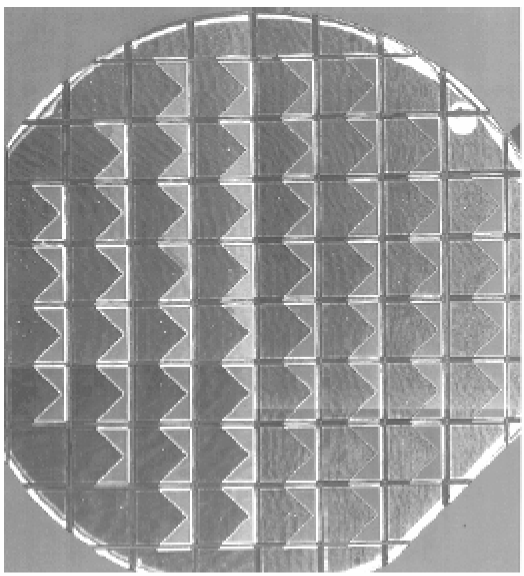


Micro-Chevron Test Example



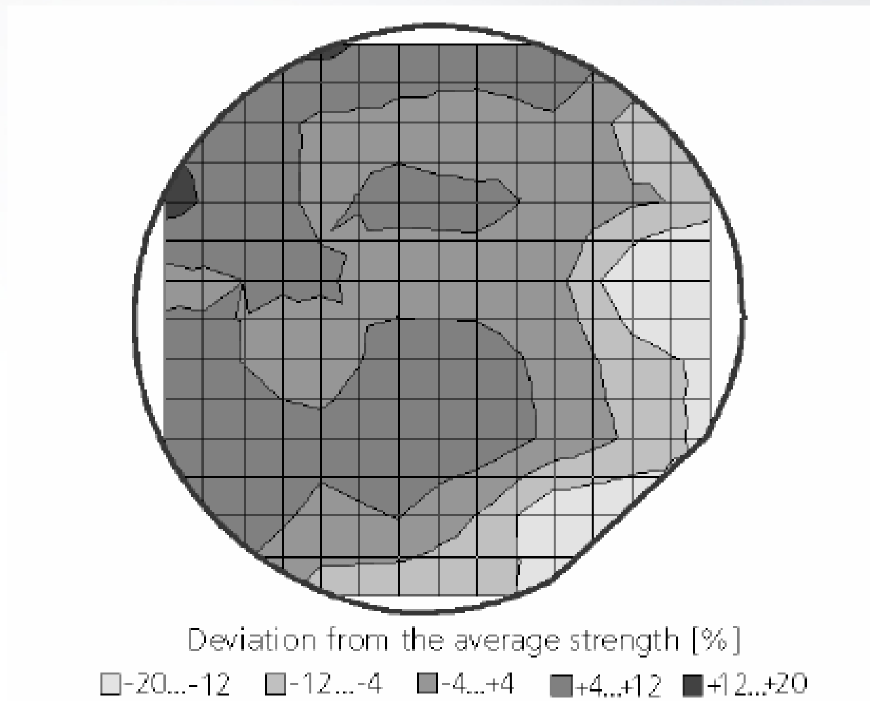
Micro-Chevron Experiment Strength vs. Position

Sample Array Interface
Si-Si Wafer Pair #1



Source: Bagdahn *et al;* Fraunhofer Institute for Mechanics of Materials

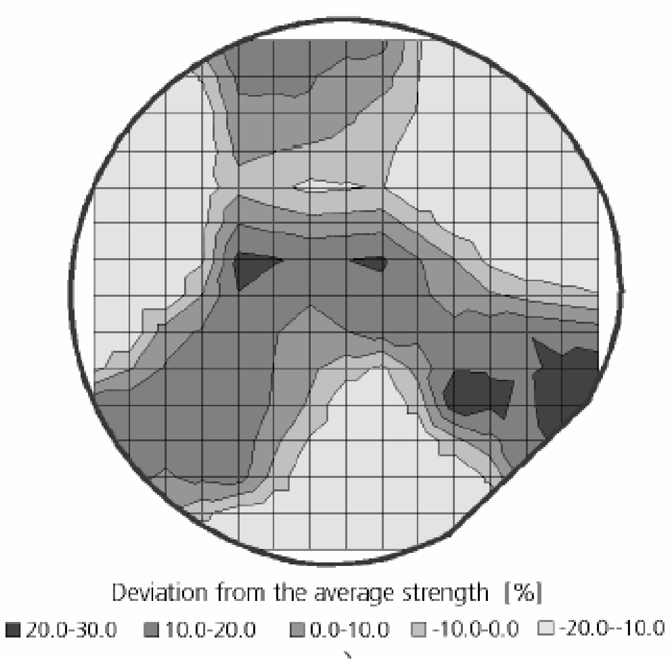
Δ Strength Distribution
Si-SI Wafer Pair #1



Micro-Chevron Experiment Strength vs. Position 2

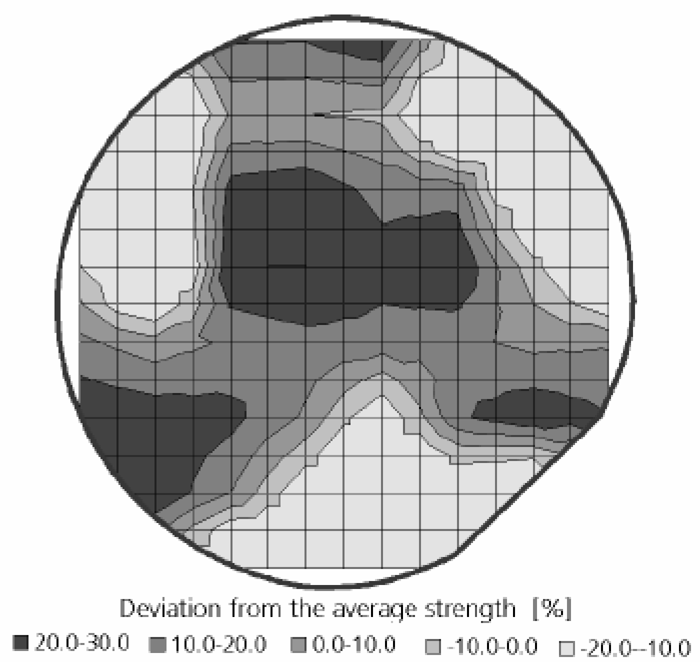
Δ Strength Distribution

Si-Glass Wafer Pair #1



Δ Strength Distribution

Si-Glass Wafer Pair #2



Source: Bagdahn *et al;* Fraunhofer Institute for Mechanics of Materials

MEMS Fluidics Task Force
Design Guide

Guide for Standard Performance, Practices, and Assembly for Ultra High Purity Microscale Fluidic Systems for Use in Scalable Process Environments

- Outlines necessary topics; includes source references
- Design considerations; materials issues; connections; subsystems; interfaces
- Published as Preliminary Standard 7/05
- Development continues

Note: Project defined and led by a major semiconductor manufacturing equipment manufacturer

MEMS Terminology Task Force

- Global SEMI collection effort
  - Initial draft of nearly 150 definitions, many duplicates
  - Weeded, edited, re-formatted
  - Reviewed for technical issues
  - Approved as SEMI Preliminary Standard 7/05
    - Contains 74 terms
  - Revisions and additions already under way

ASTM Film Stress Test Methods

Basic tool is non-contact optical interferometry

- E 2244: in-plane length of thin films
- E 2245: residual strain in thin films
- E 2246: strain gradient in thin films
  - NIST round-robin tests of these methods aided by SEMI cooperation
  - ASTM terminology from these standards is included (by permission) in SEMI Preliminary Standard
- E 2444 Terminology Relating to Measurements Taken on Thin, Reflecting Films

NanoLand

SEMI Nanoparticles in Slurry for CMP (Chem-Mechanical Polishing)

- 2Q05 Survey – Slurry Users, Material Suppliers
  - Goal: Develop *Guide for Characterizing Nanoparticles for Use in CMP Slurry*
  - Review Draft in Portland Oregon October 10
- Nanoparticle: ≤ 100 nm equivalent diameter, after capillary membrane separation
- Manufacturing Processes:
  - Pyrogenic, TEOS Hydrolization, Fumed SiO2
  - Resultant Compositions: Al_2O_3, CeO_2, SiO_2
- Size distribution: 20 – 80 nm, typical

SEMI Nanoparticles in CMP Slurry 2

Important Characteristics	2005	Future
Surface		
Smooth, Nearly Spherical	50%	60%
Highly Irregular	40%	10%
Electrical		
Electrochemical Surface Potential (when in slurry)	50%	40%
Purity		
High < 1000 ppb Highest < 1 ppb	10%	10% 10%

SEMI Nanoparticle Metrology

- In Use
  - SEM 60%
  - Others: Particle Size Analyzer, Particle Size Distribution, Abrasive Surface Charge
- Challenges
  - SEM for < 100 nm; non-dry condition
  - Fast Particle Surface Geometry
  - Chemical Property Analysis

	2005	*Future*
• Dispersion	X	X
• Hydrophilic	X	X
• Free Metal Pollution	X	
• Low Pollution		X

IEEE Standards for Nanotechnology

- IEEE P1650™, Standard Test Methods for Measurement of Electrical Properties of Carbon Nanotubes
  - Initial Sponsor Ballot closed 8/18/05
- IEEE P1670™, Chemical Vapor Deposition Techniques for Nanotechnologies Including Measurements and Analysis to Control CVD Nanoscale Processes – under development
- IEEE Quality Study Group on Carbon Nanotubes
  - Project approval being sought

ASTM Committee E56 on Nanotechnology

- Proposed a year ago; over 100 members to date
- More than 16 countries represented
  - Vice Chairman is from AIST
- Subcommittees:
  - Terminology and nomenclature – draft balloting now
  - Characterization – first draft test method balloting now
  - Environmental and Occupational Health and Safety
  - International Law and Intellectual Property
  - Liaison and International Cooperation
  - Standards of Care and Product Stewardship

ISO TC229 on Nanotechnologies

- Proposed by UK 1/05
- Supported by ANSI and 24 other countries 4/05
- ISO authorized TC formation 7/05
  - – UK has TC secretariat
  - – Proposed subcommittees and probable secretariats:
    - Terminology and Nomenclature – UK
    - Metrology – Japan
    - Environmental and Occupational Health and Safety – US
- First meeting November 9-11 in London

Questions?